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Single-Channel Ground and Airborne Radio System (SINCGARS) Operator Training Evaluation

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Richard L. Palmer
U.S. Army Research Institute

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IELD	GROUP	SUB-GROUP	Combat net radios	Cost	Critical tasks
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			Complexity	Cost-effectiveness	(Continued)

3STRACT (Continue on reverse if necessary and identify by block number)
The Single-Channel Ground and Airborne Radio System (SINCGARS), which is replacing :ent Army combat radios, requires much more operator training than the radios. Training ıuation for SINCGARS was performed by the U.S. Army Research Institute using data col- :ed from April to November 1988. Evaluation objectives were to (a) assess training ef- ɩency; (b) relate critical task performance times to Training and Doctrine Command ADOC) testing criteria, Armed Services Vocational Aptitude Battery, SINCGARS Learning- ention Test, class size, student-to-instructor ratio, and student-to-radio ratio; document operator performance deficiencies; (d) document student evaluation of the ɩning; (e) measure operator performance decrement over time; and (f) measure effects shortening training from 32 to 24 hours.

The major findings of the evaluation were the following: (a) 28% of student classroom :s were unrelated to ongoing instruction; idleness increased from 7 to 59% during the (Continued)

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ICOM	Operational test	Skills decay
Instructional methods	Performance decay	SLRT
ITT	Radio	Training
Knowledge decay		

19. ABSTRACT (Continued)

course; (b) unused time for assisting instructors varied from 36 to 77% for half days; (c) TRADOC performance criteria for critical tasks were extremely lenient, effectively guaranteeing that almost all students would qualify as SINCGARS operators regardless of performance; (d) several crucial operational procedures were not well learned; (e) class size, student-to-instructor ratio, and student-to-radio ratio were unrelated to performance; (f) the most frequent student criticism was that the course was too long; (g) SINCGARS training development includes no effective feedback loop for improving training; (h) decrement in operator performance during 2-1/2 months without practice was 20%; performance after 1 month's training may, without practice, drop 10 to 15% within 6 to 8 weeks; and (i) critical task performance times did not differ between a 24- and 32-hour course, which strongly suggests that SINCGARS training can be made more cost-effective. Training improvement suggestions were made in several areas, including course content, instructional procedures, and operator's manuals.

Life-cycle costs for SINCGARS training could reach $6 billion. This research suggests that half of these funds could be saved by incorporating certain readily made changes into the SINCGARS training program and by instituting a training research and development project designed to improve training while maximizing cost-effectiveness.

Research Report 1579

Single-Channel Ground and Airborne Radio System (SINCGARS) Operator Training Evaluation

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Human Factors in Training and Operational Effectiveness

FOREWORD

The Systems Research Laboratory of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) conducts manpower, personnel, training, and human performance research associated with the development, acquisition, and operation of Army systems. The project reported here, conducted by the laboratory's Fort Hood Field Unit, is part of an overall MANPRINT evaluation of the Single-Channel Ground and Airborne Radio System (SINCGARS) begun in 1982. SINCGARS will replace all of the Army's single-channel combat net radios and will be the primary secure voice means for short-range communications. The results of the system MANPRINT evaluation have led to significant hardware and software modifications that have effectively increased the operability of the system.

The current effort was part of the Fort Hood Field Unit's research task "Soldier-System Considerations in Force Development Testing," and was conducted in 1988 in conjunction with the U.S. Army Test and Experimentation Command's "Follow-On" and "Early User" test-and-evaluations of the SINCGARS system. The research concentrated on SINCGARS operator training and on the post-training decay of the operator's skills and knowledge over time. It demonstrates that very substantial savings in time and dollars can be achieved by maximizing the cost-effectiveness of SINCGARS training through research and development.

The key organizations to receive this report include the Office of the Deputy Chief of Staff of Personnel, MANPRINT Directorate; the Training and Doctrine Command (TRADOC) (the SINCGARS System Manager); the Communications and Electronics Command (the SINCGARS Project Manager); the Operational Test and Evaluation Agency (the SINCGARS independent evaluator); and the Test and Experimentation Command (the SINCGARS testing agency).

This research was conducted in accordance with the provisions of a Memorandum of Understanding between ARI and the TRADOC Combined Arms Test Activity (now the Test and Experimentation Command Combined Arms Test Center) dated 7 May 1981.

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ACKNOWLEDGMENT

Much of the operator performance decay data for this study, as well as certain field data and biographical data, were collected by U.S. Army Research Institute for the Behavioral and Social Sciences research psychologist Louis W. Buckalew.

SINGLE-CHANNEL GROUND AND AIRBORNE RADIO SYSTEM (SINCGARS)
OPERATOR TRAINING EVALUATION

EXECUTIVE SUMMARY

Requirement:

The Single-Channel Ground and Airborne Radio System (SINCGARS) is replacing the Army's single-channel combat net radios. Training evaluation for SINCGARS was performed by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) in conjunction with two SINCGARS tests conducted by the Army Test and Experimentation Command under the auspices of the Army Operational Test and Evaluation Agency: (a) the Follow-On Operational Test and Evaluation (FOTE) of the modified advanced development model (April-May 1988); and (b) the Early User Test and Evaluation (EUTE) of the integrated communications security model (October-November 1988). The objectives of the evaluation were the following:

1. To determine the efficiency of the 32-hour FOTE operator training course in its expenditure of time (for both students and instructors).

2. To evaluate the effects of shortening training from 32 to 24 hours.

3. To relate operator critical task performance times to testing criteria established by the Army Training and Doctrine Command (TRADOC); Armed Services Vocational Aptitude Battery scores; SINCGARS Learning-Retention Test (SLRT) scores; class size; student-to-instructor ratio; and student-to-radio ratio.

4. To identify common post-training performance errors of operators and weaknesses in their skills and knowledge base.

5. To estimate post-FOTE operator performance decrement over time (6, 11, and 16 weeks), and to validate previous studies of operator performance decay.

6. To document the operators' evaluation of the quality of their training and training materials.

Procedure:

Biographical and other personnel data were obtained on the FOTE operators. The operators' assessments were obtained with a training evaluation questionnaire. Evaluator observations were recorded as events occurred, and the expenditure of class time was documented on a minute-by-minute basis.

Operator performance measures (critical task times and SINCGARS Learning-Retention Test (SLRT) scores) were taken after FOTE and EUTE training and at

intervals up to 3-1/2 months after the FOTE. Previous performance decay results were compared with the current results. The effects of class size, student-to-radio ratio, and student-to-instructor ratio were evaluated. Operator performance errors were tracked.

Findings:

1. Unused time: During 9 hours (28%) of the 32-hour course, students were either idle or engaged in unrelated activities. (This is an extremely conservative estimate of the percentage of course time not optimally used.) For the students, unused course time increased steadily, ranging from 7% the first morning to 59% the last afternoon. The mean unused time for two assisting instructors was 59%, varying from 36% to 77% for half-day periods.

2. TRADOC performance criteria: Critical task performance times required for passing the course were extremely lenient--averaging over three times as long as the students needed.

3. Training deficiencies: Certain crucial procedures were not well learned by some students.

4. Class size: Unrelated to performance. Almost doubling class size from 22 to 42 produced no apparent negative effect. Indeed, students in the larger class appeared to perform somewhat better.

5. Student/instructor ratio: Unrelated to performance. Doubling students per instructor from 7 to 14 had no noticeable effect.

6. Student/radio ratio: Unrelated to performance. Increasing the student-to-radio ratio from 1.7 to 3.2 did not reduce student performance.

7. Course evaluation by students: The most frequent comment was that the training was too long.

8. Post-training performance decay: After about a month of training and experience, performance drops 10 to 15% during the first 6 to 8 weeks without practice and about 20% after 2-1/2 months, leveling off during the third month.

9. Critical task performance times did not differ between the 24-hour EUTE course and the 32-hour FOTE course. This finding strongly suggests that SINCGARS training can be made more cost-effective.

Utilization of Findings:

Previous ARI research has yielded significant changes in SINCGARS hardware and software. Additional human-factors engineering findings are noted in this report, but the majority are reported earlier and not repeated.

SINCGARS training has no formalized mechanism by which lessons learned are incorporated into future training. This research suggests many ways in

which the training could be improved. Observations are presented that relate to course content, instructional procedures, and the operator's manuals.

The life-cycle cost of SINCGARS training could reach nearly $6 billion. Half of these funds could be saved by reducing course length, increasing class size and students per instructor, and by research and development designed to maximize the cost-effectiveness of the training.

SINGLE-CHANNEL GROUND AND AIRBORNE RADIO SYSTEM (SINCGARS)
OPERATOR TRAINING EVALUATION

CONTENTS

LIST OF TABLES

LIST OF FIGURES

SINGLE-CHANNEL GROUND AND AIRBORNE RADIO SYSTEM (SINCGARS)
OPERATOR TRAINING EVALUATION

Introduction

Background

This evaluation is part of the overall Manpower and Personnel Integration (MANPRINT) evaluation of the Single-Channel Ground and Airborne Radio System (SINCGARS) being conducted by the U.S. Army Research Institute (ARI). The evaluation began in 1982 with the Army's initiation of operational testing on the system. Much of the current data was collected in conjunction with the Follow-On Operational Test and Evaluation (FOTE) of SINCGARS, performed by the U.S. Army Test and Experimentation Command (TEXCOM) at Fort Sill during the period March to May 1988. Tne remaining data were obtained throughout the following months in follow-up efforts and during operator training that took place prior to the Early User Test and Evaluation (EUTE) of the SINCGARS Integrated Communications Security (ICOM) model. The EUTE was also conducted by TEXCOM; it took place at Fort Hood in October 1988.

The SINCGARS model tested in the FOTE was the Modified Advanced Development Model (MADM), otherwise known as the "production" or "vanilla" radio. The latter characterization is derived from the fact that the MADM is the original, "plain" version without internal communications security. Its successor, the ICOM model, incorporates additional communications security (COMSEC) features that obviate the use of external COMSEC equipment (specifically, the VINSON TSEC/KY-57).

The advent of the ICOM radio has resulted in a curtailed production of the MADM in anticipation of Army-wide distribution of the ICOM. (A small number of vanilla radios were deployed in Korea prior to the FOTE under an early distribution plan.) The operational similarity of the two models is very high. Hence, had the ICOM been used during this evaluation rather than the MADM, similar findings would have been anticipated.

System Description

The SINCGARS radio is a VHF-FM receiver-transmitter developed and manufactured by ITT Corporation (Aerospace/Optical Division). The radio will replace the Army's current AN/PRC-77 and AN/VRC-12 series of single-channel combat net ground radios and the AN/ARC-114 and AN/ARC-131 aircraft radios. The ground radio is provided in a backpack version (AN/PRC-119) and six different vehicle-mounted versions (AN/VRC-87 through 92). The primary role of SINCGARS is to provide secure voice transmission for the command and control of maneuver forces. It will be the primary means for short range communications at echelons below division level and for combat support and combat service support units throughout corps level.

One of the most significant feature of SINCGARS is its jam-resistance, or electronic-counter-counter-measure (ECCM) mode, accomplished by "frequency-hopping." In this mode, the radio changes transmission frequency many times a second. All radios in a net are capable of hopping simultaneously from one frequency to another within a prescribed set of many frequencies called a

hopset. The radio is also capable of single-channel (non-frequency-hopping) communication, data transmission, and channel scanning. It has push-button tuning, a light-emitting diode display, selectable power outputs, a whisper mode, an expanded frequency range (as compared with the current radios), built-in test capability, and nuclear hardening against electromagnetic and radiation effects. As noted, the ICOM version has additional COMSEC features.

Evaluation Objectives

The evaluation had six primary objectives:

1. To determine the efficiency of the 32-hour FOTE operator training course in its expenditure of time for students and instructors.

2. To evaluate the effects of shortening allotted training time for SINCGARS operators from 32 to 24 hours.

3. To relate operator critical task performance times to the following:

- SINCGARS operator testing criteria established by the U.S. Army Training and Doctrine Command (TRADOC)
- Operator scores on the Armed Services Vocational Aptitude Battery
- Operator performance on the SINCGARS Learning-Retention Test (SLRT)--a simulated hands-on performance instrument
- Class size
- Student-to-instructor ratio
- Student-to-radio ratio

4. To identify common post-training performance errors of operators and weaknesses in their skills and knowledge base.

5. To estimate post-FOTE operator performance decrement over time intervals of approximately 6, 11, and 16 weeks and to validate previous studies of skills and knowledge decay in SINCGARS operators.

6. To obtain operator evaluation, commentary, and suggestions pertaining to the quality of their training and training materials.

Methods and Results

Description of Operator Training Course and Students

The one-week outstation operator's course conducted in preparation for the FOTE was developed by TRADOC. It consisted of four days of instruction followed by a day for individualized testing. Instructors were from Fort Sill and the Signal School at Fort Gordon. The course did not include formal net control station training and retransmission training, which were taught separately and not observed for this evaluation. Sixteen classes (four at a time) were taught over a one month period that commenced on 29 February 1988. During each week, two classes were conducted during the day (0800-1630) and two at night (1730-0230) in two classrooms.

The two classrooms were very similar. Both contained 13 radios and were prepared to accommodate 26 students at a time, 2 students per radio. There were 12 different instructors, 3 per class. The total number of students taught during the month was 367--an average of 22.9 students per classroom. The actual number of students in a classroom varied, however, from 11 to 42, as shown in Table 1. The number of radios remained constant.

Table 1

Training Groups

Class Number	Week	Shift	Class-room	Class size
1	1	Day	A	26
2	1	Day	B	26
3	1	Night	A	21
4	1	Night	B	24
5	2	Day	A	22
6	2	Day	B	26
7	2	Night	A	24
8	2	Night	B	26
9	3	Day	A	25
10	3	Day	B	26
11	3	Night	A	11
12	3	Night	B	11
13	4	Day	A	42
14	4	Day	B	17
15	4	Night	A	26
16	4	Night	B	14
			Total:	367

Eighty-six percent (315) of the students came from units located at Fort Sill. Others came in various numbers from other military posts in the United States (Forts Bliss, Bragg, Campbell, Carson, Hood, Lewis, and Polk). (Location of duty station was unavailable for 29 students.) Tables 2-4 present student personnel data that were obtained as variables that might be useful in evaluating the training results. Military rank was obtained from classroom rosters; military occupational specialty (MOS) and Armed Services Vocational Aptitude Battery (ASVAB) scores were obtained from records kept in the soldiers' unit files: The EL score reflects the student's facility in arithmetic reasoning, math knowledge, electronics information, and general science; the GT score reflects a verbal composite and arithmetic reasoning; the SC score concerns numerical operations, coding speed, auto and shop information, and the verbal composite.

Detailed observations were made by ARI during two of the 16 course iterations. Events and situations related to the variables under examination were documented as they occurred.

Table 2

Student Body Descriptors: Military Rank

Rank	Frequency	Percent[a]
PV1	2	<1
PV2	62	20
PFC	26	8
CPL/SP4	134	43
SGT	42	14
SSG	32	10
SFC	12	4
Total frequency:	310	

Note. Rank data were missing for 57 students.
[a]Percent of available data. (Available: 367 - 57 = 310.)

Table 3

Student Body Descriptors: Primary MOS

MOS	Frequency	Percent[a]	MOS	Frequency	Percent[a]
11B	32	10	21G	7	2
11C	39	13	31K	10	3
13B	40	13	63B	5	2
13E	15	5	63Y	4	1
13F	41	13	76C	5	2
13N	11	4	76Y	9	3
15E	19	6	88M	5	2
19D	4	1	Misc.[b]	42	14
19E	18	6			
			Total frequency:	306	

Note. MOS data were missing for 61 students.
[a]Percent of available data. (Available: 367 - 61 = 306.) [b]Miscellaneous MOSs: the total of miscellaneous MOSs that individually were less than one percent of the available data.

Table 4

Student Body Descriptors: ASVAB[a] Scores

Score	Frequency[b]	Mean
Electronics Repair (EL)	270	105.7
General Technical (GT)	271	106.2
Surveillence & Communications (SC)	264	107.6

[a]Armed Services Vocational Aptitude Battery. [b]Available data. ASVAB scores were not obtained for the rest of the 367 students.

Course Efficiency Analysis

Purpose

The purpose of this analysis was to obtain an accurate estimate of how efficiently the basic SINCGARS operator course used student manhours. The only time periods counted as inefficient for any student were those during which the student was, for purposes of the course, virtually idle--that is, not engaged in learning-related activity. A certain amount of inefficiency is, of course, inherent in any course of instruction. Therefore, the objective of the analysis was not to imply that every wasted manhour can be eliminated, but to provide a baseline against which future course improvements can be evaluated.

Course Characteristics

Nominal. Training was scheduled for four days. (On the fifth day the students were to be tested.) The total number of scheduled course hours, including lunch and study breaks, was 34. The total number of scheduled instructional hours, which excludes breaks, was 22 (5.5 hours per day). Daily sessions were to extend from 0800 to 1630 with four 20-minute study breaks (two in the morning and two in the afternoon) and a lunch break of 1 hour 40 minutes (from 1130 to 1310). There were to be 3 instructors, about 26 students, 13 radios, 13 operator's manuals (10-1), and 13 operator's pocket manuals (10-2).

Actual. The characteristics of the actual course were very close to the nominal characteristics. The primary discrepancy was the number of students, which was 42 rather than 26, making this particular class the largest of the 16 classes taught during the month. A comparison of the nominal course schedule and the actual schedule is depicted in Table 5.

Procedure

One of the 16 courses (4th week, day shift, class 1) was observed in its entirety and comprises the basis for this analysis. At regular intervals (often as short as one minute) the course evaluator recorded the number of students who appeared not to be engaged in any course-related learning activity whatsoever, either active or passive. If it was not obvious that a student was idle, the observation was not counted.

Table 5

Actual Versus Nominal Course Parameters

Day	Instruction (5.5)	Lunch breaks (1.7)	Study breaks (1.3)	Total (8.5)
1	5.6	1.7	1.3	8.6
2	5.5	1.7	1.4	8.6
3	5.6	1.5	1.4	8.5
4	5.2	1.7	1.6	8.5
Total:	21.9 (22.0)	6.6 (6.7)[a]	5.7 (5.3)[a]	34.2 (34.0)

Note. All values are hours. Nominal values are given in parentheses.
[a]Discrepancy is due to rounding error.

Similar observations were made of the assisting class instructors. At any given time, one of the three instructors was in charge of the class, while the other two assisted as requested or as they saw fit. The use of time by the instructor actually conducting the class was not evaluated; that is, it was never counted as inefficient, regardless of the instructor's effectiveness. However, a close accounting was made of the extent to which the two assisting instructors participated in the ongoing instructional activities. As in the assessment of student participation, the only time counted as inefficient for the assisting instructors was that during which there was no discernible instruction-related effort.

Efficiency Results for Students

Figure 1 portrays the percentages of idle hours during all half-day course segments. Two strong trends are apparent: The number of idle student hours increased (a) from morning to afternoon on each of the four days and (b) from Day 1 through Day 4 for both morning and afternoon sessions. Indicative of the strong increases in idleness as the course progressed is the fact that the percentages for Mornings 2, 3, and 4 were each higher than the overall percentage for the previous day.

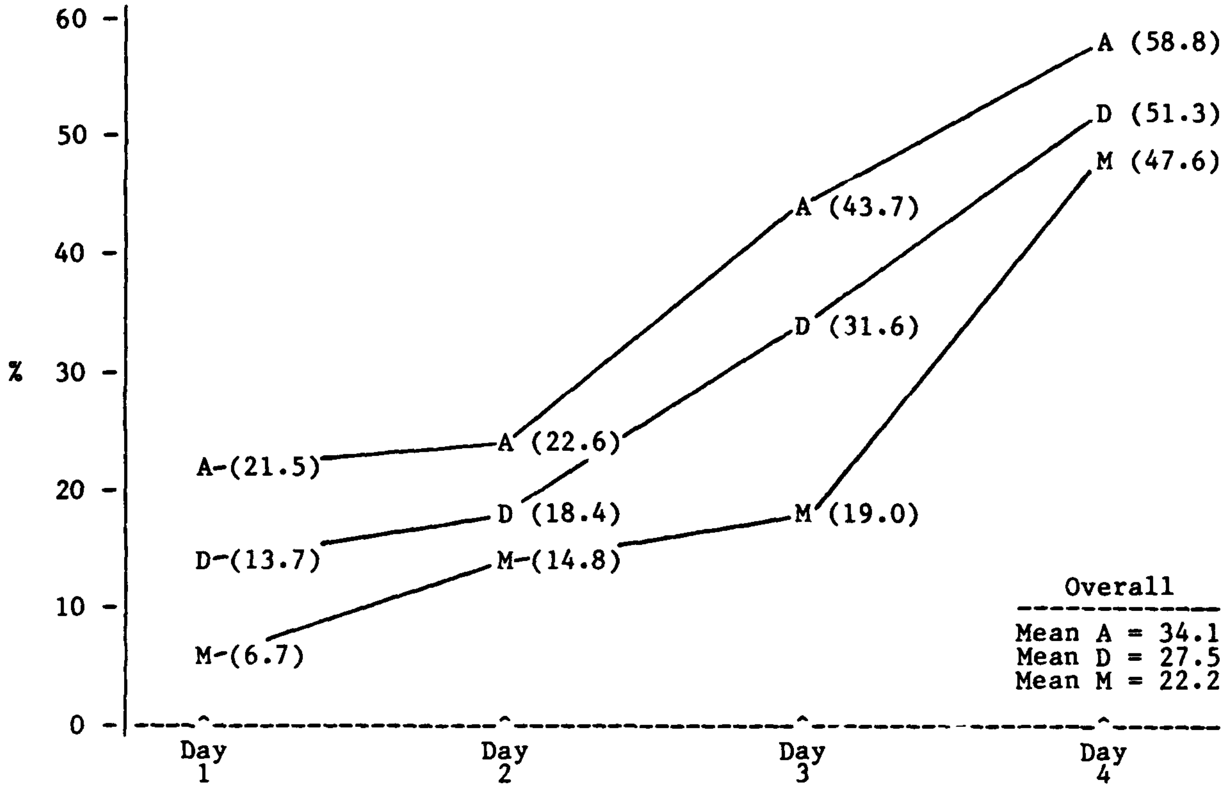


Figure 1. Idle student time: percentage of instructional hours unused by students. (M = Morning; A = Afternoon; D = All Day. Values for all day were calculated from morning and afternoon values, each weighted by amount of time observed. The overall means for M, A, and D were calculated across days, each day weighted by amount of time observed.)

Table 6 is based upon the distinction between classroom time and consumed time. Classroom time is the instructional time provided--literally the amount of time the students spent in the classroom. Consumed time is the amount of student time during which at least minimal learning activity was observed. The table shows the effect of subtracting idle (unconsumed) time from actual instructional time.

Table 6

Instructional Hours Consumed by Students

Day	Hours used[a]	% of actual time available[b]	% of nominal time available[b]
1	4.8	85.7	87.3
2	4.5	81.8	81.8
3	3.8	67.9	69.1
4	2.5	48.1	45.5
Overall:	15.9	72.6	72.3

[a]The values in this column were calculated with the formula $X[(100 - Y)/100]$, where X = the <u>actual</u> value from the <u>Instruction</u> column in Table 5 and Y = the corresponding "all day" value from Figure 1. [b]See Table 5.

In interpreting Table 6, one must remember that the difference between classroom time and consumed time is the amount of totally nonproductive student time. The hours-consumed values include all instructional time consumed regardless of its effectiveness. Hence, overall hours consumed represents a rather conservative estimate of the amount of time that basic SINCGARS operator training might be expected to require if it were conducted with maximal efficiency. The cause of most of the non-use of instructional time can be directly attributed to the lack of structured activities for the students.

A miscellaneous finding of interest was that idleness tended to increase in proportion to the distance between the students and the front of the room (instructor).

Efficiency Results for Assisting Instructors

It must be stressed that no attempt was made in the evaluation to assess instructor effectiveness. The data do not reflect the relative abilities of the instructors involved in the course. Each of them appeared genuinely dedicated to the goal of providing quality training to their students.

Figure 2 for instructors is analogous to Figure 1 for students, except that the data do not reflect time unused by the instructor in charge, which was minimal. It shows the percentages of unused instructor time for the assisting instructors for each half-day session during the first three days of the course. The evaluator did not record observations pertaining to the instructors on the fourth day because of conflicting requirements; however, the amount of unused time on the fourth day appeared to be as great or greater than on the previous day.

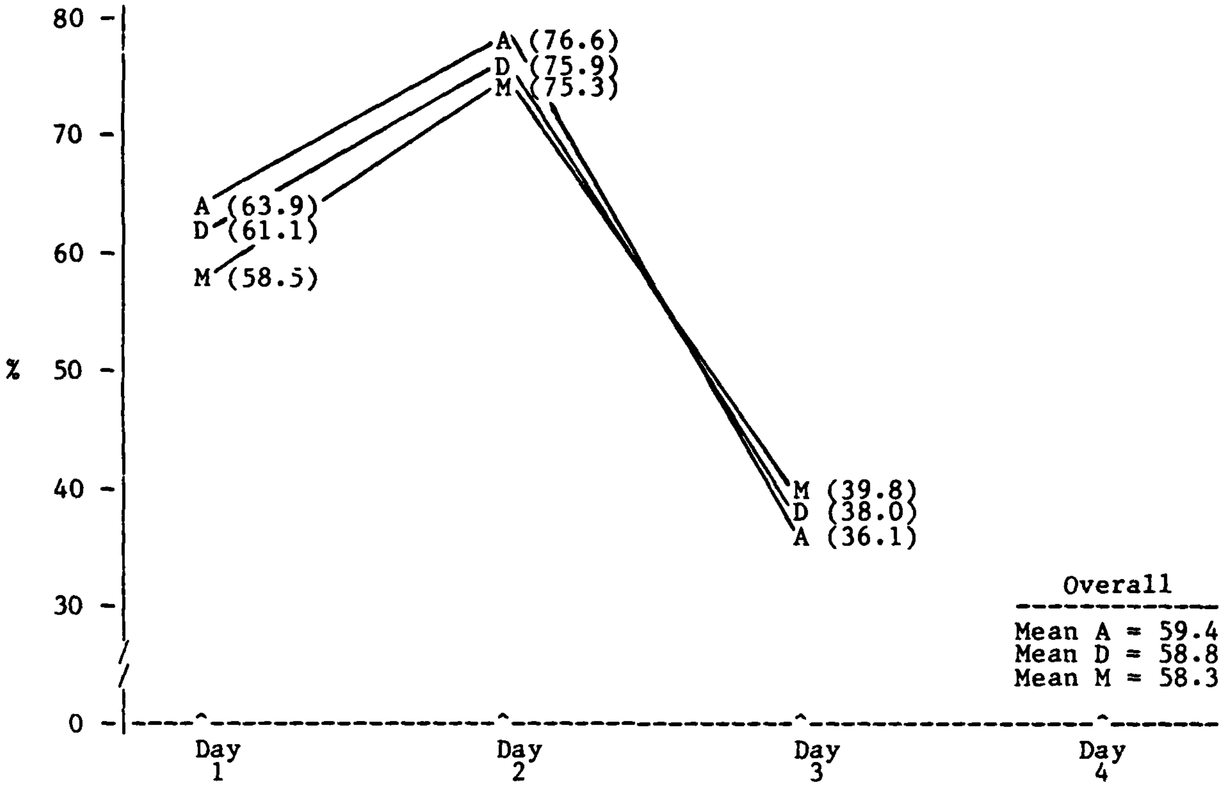


Figure 2. Idle assisting-instructor time: percentage of instructional hours unused by assisting instructors. (M = Morning; A = Afternoon; D = All Day. Values for all day were calculated from morning and afternoon values, each weighted by amount of time observed. The overall means for M,A, and D were calculated across Days 1, 2, and 3,each day weighted by amount of time observed. Data for Day 4 were not recorded.)

Like the pattern for students, the pattern for assisting instructors showed an increase from Day 1 to Day 2. The 3rd Day, however, consisted of a great amount of loosely structured and unstructured student practice, during which the instructors often mingled with the students to answer questions, solve equipment problems, and so forth. Day 4 was similar to Day 3, although perhaps even less structured.

Table 7 expresses the results for assisting instructors as the amount of instructor time that involved at least minimal instructional activity, irrespective of its extent or effectiveness. It is evident from the table that almost 60 percent of the assisting instructors' time was <u>not</u> utilized. As was true for the student data, these data, taken as an estimate of the amount of time used ineffectively, are conservative. Furthermore, it is likely that instructor utilization would be even less efficient in smaller classes, where it is expected there would be less demand for their services. This hypothesis would, however, have to be tested.

Table 7

Instructional Hours Utilized by Assisting Instructors

Day	Hours used[a]	% of actual time available[b]	% of nominal time available[c]
1	4.3	38.4	39.1
2	2.7	24.5	24.5
3	6.8	60.7	61.8
4	(Unrecorded)	na	na
Overall[d]:	13.6	40.7	41.2

[a]Calculated from the formula $X[(100 - Y)/100]$, where X = hours available (see note b) and Y = the corresponding percentage from the corresponding "all day" value from Figure 2. [b]Eleven hours available per day (5.5 hours per instructor). [c]See Table 5. [d]First three days only.

Post-Training Testing: Criterion Test (Final Exam)

Procedure

At the end of the 32-hour block of basic operator training, all students were given two performance tests. The first, the criterion test, was part of the official TRADOC training materials and was administered individually by the instructors. On the average, the test required about 25 minutes to complete. Actual administration times varied from student to student as a function both of the skill of the student and the administrative style of the instructor (some instructors conducted the procedure faster than others).

The test itself consisted of 18 hands-on performance tasks. Each task was to be completed by the student in a prescribed amount of time and scored as a "go" or a "no go." The time limits, or criteria, were determined by TRADOC training supervisors, who based them on estimates of the time required for the slowest students to accomplish the tasks. Thus the criteria allowed ample time for completing the tasks. The test, designed for screening out only those who exhibited very extreme performance shortcomings, allowed approximately 99 percent of the students to pass the course. It is not feasible, however, that 99 percent of the students would have been able to complete all of the critical tasks on the criterion test without errors; therefore, it is assumed that a trial-and-error approach to task accomplishment occurred. It was observed in some instances that some of the instructors would provide corrective feedback to students during the testing. In this regard, it is noted that the practice of occasionally assisting the student who cannot proceed with the test because of a fatal error, does not violate the objective of eliminating only students with very extreme performance shortcomings, so long as the instructor does not "pass" students who are essentially incapable of performing even at a minimal level.

Owing to the go/no-go nature of the scoring and the liberal time limits, the criterion test was not capable of making distinctions among students; that is, it did not measure any dimension of performance quality. To provide for such discrimination, it was arranged to have student performance on the 18 criterion tasks timed. The administering instructors timed each task performance with a stopwatch and recorded the times on the criterion test scoring sheets. Students who failed to perform a task within the prescribed criterion time were allowed to continue until the task was completed or until it became obvious that the student was essentially incapable of performing the task. Task performance time thus became available for use as a criterion variable in the current training evaluation; the data also constitute an objective basis for selecting future test criteria.

A detailed breakdown of the 18 critical tasks performed by the trainees on the criterion test is provided in the appendix to this report. It lists much of what the SINCGARS trainee must learn in order to operate the radio as an outstation net member and thus portrays the nature of the course content.

Criterion Task Performance Results

Table 8 shows the mean performance time for each of the 18 criterion tasks. The means were calculated from the individual performance times of all students who took the test during the month of basic operator training. It is perhaps notable that the largest consumer of time other than assembling and disassembling the radio was task 3, setting up the associated external KY-57 communications security equipment (VINSON). Also, considering the basic simplicity of task 8 (perform channel scanning), task 11 (load time-of-day), task 13 (set radio for temporary storage), task 15 (prepare to receive ERF), and task 16 (store ERF), the corresponding mean times required suggest that some students were confused about correct operational procedures for these tasks.

The table also shows a large discrepancy between the criterion times established by TRADOC and the actual performance times. The criterion time allotted for completion of a given task ranged from two to eight times the amount actually required to complete the task. On the average, criterion times were three times as great as the performance times. It is evident, then, that the criteria, without revision, would serve no practical purpose in future testing. On the other hand, the mean performance times could very well serve as a rough guideline for establishing new criteria. What is needed to complement them, however--besides replication in other classes to assess their reliability--is validation data derived from the performance of highly skilled and experienced operators, the latter to serve as an ideal standard that students can be made to strive for.

The mean total performance time to complete all criterion tasks was about 12 minutes.

Table 8

Criterion Task Performance Times

	Critical task	TRADOC criterion times	Mean performance time
1.	Assemble the SINCGARS AN/VRC-90 radio set	300	158
2.	Turn on & test radio	60	20
3.	Turn on, clear, & load TSEC/KY-57 (VINSON)	180	59
4.	Set battery condition	60	14
5.	Load manual, cue, & 2 single-channel frequencies	180	53
6.	Perform communications check on manual channel	120	21
7.	Set frequency offset on 1 channel	60	18
8.	Perform channel scanning (non-priority)	120	36
9.	Load & store TRANSEC variable	120	41
10.	Load & store 2 hopsets	120	46
11.	Load time-of-day	180	41
12.	Perform communications check (frequency hopping)	180	32
13.	Set radio for temporary storage	60	8
14.	Cue the net control station	120	38
15.	Prepare to receive ERF	60	17
16.	Store ERF	120	15
17.	Perform communications check (frequency hopping)	60	13
18.	Zero radio, set for long-term storage, & disassemble radio set	240	92
	Mean:	130	40

Note. Times are given in seconds.

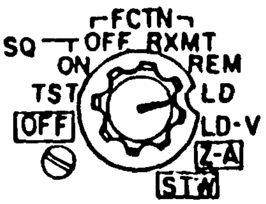
Post-Training Testing: SINCGARS Learning-Retention Test (SLRT)

Procedure

The SLRT is a 34-item, paper-and-pencil, simulated hands-on performance test. It has been used since 1983 to measure relative skill and knowledge levels, and the retention of those levels over time, in SINCGARS operators. It has been shown that groups of operators achieve similar mean scores on the SLRT administered in similar situations. In its current version, it covers seven critical operational skills and nine critical areas of knowledge. The student circles appropriate answers on items of varied formats. Designed for face validity, all of the skills items and many of the knowledge items simulate the physical and visual aspects of the real task; e.g., the student is asked to circle the correct answer on a multiple-choice item that has the physical appearance of one of the controls on the radio, as illustrated in Figure 3.

The SLRT was administered in group sessions by the ARI evaluator to all students in all 16 classes immediately following their instructor-administered final examinations.

The function switch on the radio looks like this:



The function switch is represented like this in the SLRT:

```
        <FCTN>
  ----------------
   SQ OFF    RXMT
  SQ ON        REM
   TST          LD
  OFF           LD-V
               Z-A
            STW
```

Figure 3. Illustration of the similarity between the physical features of the radio and their representation in the SLRT.

Learning-Retention Results: Skills and Knowledge Scores

Tables 9 and 10 show the SLRT results for the 362 students who took the test during the month of training. (Five of the original 367 students were lost because of normal attrition.)

Of particular note in Table 9 are the following weak spots: testing the radio's memories (a topic that needs special emphasis in the classroom because of the lack of appropriate labeling on the function switch and inadequate coverage in the operator's manual); electronic-remote-fill procedures; and the procedures for frequency offsetting.

The knowledge retention results shown in Table 10 also indicate a few weak areas, notably: setup for remote operation (remote operation was not performed in the classroom); cold start load for net members; the display indication for the secondary TRANSEC variable (not stressed in the classroom); and the procedure for entering the late entry mode. The last is especially confusing as presented in the operator's manual and as represented on the keypad of the radio; therefore, it needs special emphasis in training.

Overall, the students achieved 71.7 percent of the 408 points possible on the SLRT. This percentage is comparable to the mean percent (75.4[1]) obtained across previous operational tests of the SINCGARS radio, which indicates that the current students were similar to previous students in post-training skill and knowledge levels. However, the present students were at some disadvantage because they did not receive the formal net control station (NCS) training that the previous classes had received. Had that training been included, the overall percent correct for the current students may have been slightly higher.

---

[1]Calculated from SLRT pretest data presented in Table 21.

Table 9

Student Performance on the SLRT: Operational Skills

Task	Mean % of perfect task score
1. Test receiver-transmitter memories	7.5
2. Load & store TRANSEC variable (local fill)	88.2
3. Load & store hopset (local fill)	82.2
4. Load date & time of day	83.3
5. Send hopset (ERF)	57.9
6. Receive & store hopset (from ERF)	67.9
7. Change frequency offset	64.7

Note. For each task, the student could achieve a certain number of points. The percent shown for a task is the mean percent of possible points achieved on the task by the 362 students.

Table 10

Student Performance on the SLRT: Knowledge Retention

Knowledge area	Mean % of perfect area score
1. Single-channel frequency loading	92.5
2. Use of "STW" (stow) on the function switch	88.3
3. Setup for single-channel communications	94.2
4. NCS procedure for receiving a cue call	70.9
5. Hopset & single-channel frequency capacities of receiver-transmitter	76.1
6. Setup for remote operation	65.8
7. Cold start load for net member	44.2
8. Secondary TRANSEC variable display indication	27.5
9. Entering late-entry mode	56.7

Note. See note at Table 9.

Learning-Retention Results: Common Operator Performance Errors

The SLRT enables the tracking of many operational errors because each step of task performance is recorded by the student. It was, therefore, possible to ascertain common operational errors. It was not considered vital for the purposes of this report to produce a detailed frequency distribution of errors; instead, the most common important errors were noted and are listed in Table 11. The problem areas are seen to be similar to those described in Tables 9 and 10.

Table 11

Frequently Occurring Operator Performance Errors on the SLRT

Problem area	Problem or error description
1. Testing the memory of the radio	Very few of the operators knew how to test the radio memory, accomplished by moving the function switch to the Z-A position. Typically they would set the function switch on TST rather than Z-A. [Comment: The problem here is attributable to a human factors design deficiency. The label on the Z-A position of the function switch bears no indication of the memory-test function. Consequently, the task should be over-emphasized in training. It was not.]
2. Loading & storing TRANSEC variable	Instead of pressing only H^{O}Ld to "load & store" the TRANSEC variable, either both H^{O}Ld & Sto/ENT or Sto/ENT alone was pressed. [Comment: This problem has the potentially serious consequence of erasing the primary TRANSEC variable from the radio.]
3. Loading & storing hopsets	a. Operators failed to load the hopset by pressing the H^{O}Ld key. Instead, they would attempt to store it directly into a particular channel with Sto/ENT & a channel number. [Comment: Ideally, the radio should request the appropriate information via the display once the operator has specified the desired procedure. Since the radio is not interactive, training should emphasize the distinction between "loading" and "storing" (or "entering"), terms that can be easily misunderstood or confused.]
	b. Operators pressed the Sto/ENT & channel number keys in reverse order (channel number followed by Sto/ENT) when attempting to store a hopset. [Comment: Normal procedure at a computer terminal is to type information first, then "enter" it, not vice versa. The correct procedure for storing hopsets in the radio is to press Sto/ENT first, then the desired channel number, which is opposite to customary keyboard procedures.]
	c. Operators pressed both the H^{O}Ld & Sto/ENT keys prior to the channel number in attempting to store a hopset received by ERF instead of just Sto/ENT & the channel number. [Comment: This problem represents a confusion between the procedures for loading a hopset and those for a "cold start."]

[Table continued on next page]

Table 11, continued

Frequently Occurring Operator Performance Errors on the SLRT

Problem area	Problem or error description
4. Setting date & time-of-day	a. Operators attempted to enter time without first storing (Sto/ENT) the date. b. After storing (Sto/ENT) the date, operators attempted to set the time without pressing the TIME key.
5. ERF procedures	Operators set the channel switch to MAN to receive or send a remote fill.
6. Setting offset frequency	a. Operators entered "05" instead of "5." b. Operators attempted to enter an offset without first clearing the display. c. Operators mislocated the minus sign (SEnd/OFST key) in the series of key presses required to load a negative offset. The SEnd/OFST key is pressed either before CLR or after the offset number(s) instead of before the offset number(s). d. The function switch was unnecessarily set to the LD position before the offset was entered.
7. Differential functions of the Sto/ENT & H^{O}Ld keys	The keys were frequently confused with each other, especially when "retrieving" a hopset prior to an ERF--the operator would press Sto/ENT instead of H^{O}Ld.
8. Use of the FREQ key	The FREQ key was sometimes substituted for the H^{O}Ld key. Apparently, the functions of the FREQ key were not sufficiently familiar to operators.

Class Size, Student-to-Radio Ratio, and Student-to-Instructor Ratio

Procedure

Some of the results presented earlier were based upon observations made of the largest class taught during the month of training. It had 42 students, whereas the other classes ranged in size from 11 to 26, with an mean of 21.7 (see Table 1). Because of the larger number of students in the observation class and equipment limitations, the student-to-radio ratio was much larger: 3.2 students per radio versus 1.7, on the average, in the smaller classes. All the classes, however, had three instructors. To compare the performance of the students in the large and small classes, both the criterion test scores and the SLRT scores were combined for the smaller classes and compared to

those of the larger class. A statistical test (analysis of variance, general linear model) was used to compare the two resultant groups on both the criterion test scores and the SLRT scores.

Results

Table 12 shows the mean times for the criterion test and the mean percents correct for the SLRT. (As noted earlier, the mean percent correct for all classes combined was 71.7.) On the criterion test, the large class seemed to perform slightly better, although the result could well have been due to chance. On the SLRT, the large class again did somewhat better, and the difference was statistically significant, although not large in a practical sense. Thus, the larger class suffered no performance loss, as one might have expected; in fact, they appeared to perform somewhat better. These results indicate that (within reasonable limits) class size, student-to-radio ratio, and student-to-instructor ratio are probably not of uppermost importance for SINCGARS training. (The major differences between the large class and combined small classes in rank and MOS structure are shown in Table 13. ASVAB comparisons were not available for this report.)

Table 12

Comparison of Large Class With Smaller Classes

	Large class (mean)	All smaller classes (mean)	Statistical significance[a]
Criterion Test	11.3 minutes	12.0 minutes	$p < .25$
SLRT	75.7% correct	71.1% correct	$p < .02$

[a]Probability that the difference between the large class and all of the smaller classes combined was a chance occurrence.

Table 13

Comparison of the Rank and MOS Structures of the Large and Combined Small Classes

	Large class (%)	Combined small classes (%)
Rank		
SFC	14	2
PFC	2	9
PV2	12	21
MOS		
11B	0	12
11C	0	15
13F	49	8
13N	12	2

Note. Shown are observations that differed by more than five percentage points between the large and combined small classes.

Correlations Among Criterion Test, SLRT, and ASVAB Scores

Table 14 lists the correlation coefficients among the overall scores on the criterion test, overall scores on the SLRT (total of skills and knowledge subscores), and the ASVAB variables. All of the correlations are highly statistically significant ($p < .0001$). The highest correlations were between the SLRT and the other variables.

Table 14

Correlations (Criterion Test, SLRT, and ASVAB Scores)

	SLRT scores	ASVAB EL	ASVAB GT	ASVAB SC
Criterion Scores	.37	.26	.13	.26
SLRT Scores	...	.53	.41	.43

Note. All values are Pearson product-moment correlation coefficients.

Criterion Test Scores, SLRT Scores, and Field Performance Scores

Operational Problems in the Field

The top students in the training classes might be expected to experience fewer operational problems in the field than students at the bottom; yet, of the problems that would occur, they might be expected to detect and report more. Therefore, no prediction regarding the relation between classroom performance measures and frequency of operational field problems was made. And, in the outcome, neither the criterion test scores nor the SLRT scores were at all correlated with the number of problems (reported elsewhere) the operators later documented in the field during the FOTE record-test phases.

Operator Message-Completion Rates in the Field

The successful communication of a message in the field over the SINCGARS radio is function of many things. Nevertheless, it was of interest to determine whether the criterion test scores and the SLRT scores were related to completion rates, even though only a small set of data was available (N = 28). The criterion test scores were unrelated to message completion: the Pearson correlation coefficient was .02, indicating essentially zero correlation. The correlation of message completion rate with the SLRT scores also fell short of statistical significance, although the coefficient (.25) was somewhat larger. (It was necessary to achieve a correlation of .31 in order to be significant at the .10 level.) Although a larger sample size may have yielded significance in the latter correlation, the magnitude of the value is not large enough to be of great practical significance.

Operator Evaluation of Training

Procedure

The Training Evaluation Questionnaire for Operators (TEQO) was administered to all students in all 16 classes at the end of their training following the administration of the SLRT. The questionnaire asked them to rate the training associated with each critical operational task on two five-point scales. The first scale asked how confusing the training was, especially during the earlier part of the course; the scale ranged from <u>not confusing</u> (1) to <u>very confusing</u> (5). The second scale asked whether each task could have been learned faster had the training been different in some way; it ranged from <u>no</u> (1) to <u>very much faster</u> (5).

The TEQO also asked the students to comment on what they thought should be added to or eliminated from the course to make it more "efficient, effective, or better."

Operator Evaluation Results: Rating Scales

The rating scales indicated that the students did not perceive the critical tasks to be confusing to learn or capable of being learned a great deal faster. The mean scores for the critical tasks (calculated across all students) ranged from 1.1 to 2.0 for the <u>confusion</u> scale and from 1.7 to 2.2

for the faster scale. There is a danger of misinterpreting these results, however. It was amply evident (see student comments, next section) that many of the students felt the course was too long, and they offered many comments concerning confusion and related topics. The appropriate interpretation of the results is probably that the course content was not overly difficult and that it was capable of being learned in a reasonable amount of time.

Operator Evaluation Results: Student Comments

The students' written comments were paraphrased and organized into categories. They are summarized in Tables 15-20.[2] The frequencies shown in the tables should be noted when evaluating the comments. They should not, however, be understood as necessarily reflecting the worth of the comments. A comment made by a single respondent could be very useful.

Table 15

Student Comments About Course Content

Comment summary	Frequency
1. There needs to be more complete coverage of SINCGARS topics, such as: NCS procedures; installation, assembly, & disassembly; system configurations; PMCS; remote operations; TACFIRE operations; retransmission; data cueing; hazards; & maintenance procedures.	24
2. Instructors should not assume that students have prior knowledge or experience. Provide a more basic introduction & overview that includes some basic radio operation coverage of technical terms, & an introductory overview of the manual.	13
3. More attention needs to be paid to the "why" of procedures in order to aid retention. Give better explanations, more "theory," less rote learning.	11
4. Training on the KY-57 should occur elsewhere, not in the SINCGARS operator class.	4
5. Place more emphasis on the correct order of steps in the various operational procedures. [This is desirable in order to overcome the sometimes inconsistent or unobvious steps that must be followed for some tasks.]	2

[2]Minor editorial notations by the author are enclosed in brackets. Parentheses are used for parenthetical material from related student comments.

Table 16

Student Comments About Instructional Methods

Comment summary	Frequency
1. Provide more radios (a higher radio-to-student ratio). One radio per person.	36
2. Instruction should be more individualized, with an opportunity for some self-pacing. Some students require more work on some topics than others. There should be a lower student-to-instructor ratio. "Make the class self-paced instead of lock step. So much time was spent just going over & over things that the majority of the class [already knew], it became redundant & ended up more like a detention hall than a classroom."	26
3. The course should be more realistic in the sense of providing a more field-like environment: more nets, NCSs, and separation among the radios; real antennas & CEOIs. Conduct some training with NCS operators in another room to prevent ordinary verbal communication among station operators.	25
4. The class should be better disciplined with less commotion, less wasted time, & more structure. Rotating students for hands-on practice (while others wait) is a waste of time. There should be less "filler" material in the lectures.	20
5. Classes should be smaller. Use assisting instructors in separate, smaller classes. Sometimes the instructors have competing interests, objectives, or methods.	8
6. Night classes should be eliminated or made shorter.	8
7. There should be more frequent testing (of a structured nature) followed by remedial practice time.	7
8. Upper & lower ranks should be in different classes. Separate officers from enlisted & upper-ranking enlisted from lower-ranking enlisted. "First two days, the captain hogged RT & did everything."	3
9. Miscellaneous:	
(a) The class needs to be more interesting: "We played competition games [with the radio] for a time. That made it interesting, fun, & easier to understand & hold the information taught."	2

[Table continued on next page]

Table 16, continued

Student Comments About Instructional Methods

Comment summary	Frequency
(b) Some students acted as NCSs, others did not get a chance --"those who didn't get to be NCS missed out on a lot."	2
(c) The class should only be for communications people from the units. Once they are taught, they can teach the rest of the unit.	2
(d) Class rules should be less childish & students should receive less childish treatment.	2
(e) The course should start with a taste of hands-on. Students felt a little frustrated waiting.	1
(f) Students were not given adequate advance notice of SINCGARS training. This caused inconvenience in having to change personal plans at last minute.	1

Table 17

Student Comments About Allocation of Course Time

Comment summary	Frequency
1. The course is too long. Could be cut by one or more days. Material is too repetitive. "The last two days were spent doing almost nothing."	89
2. There should be more structured [as opposed to free play] hands-on time. Less lecture time.	26
3. The course should be longer.[3]	12
4. Miscellaneous:	
(a) Breaks should be shorter or fewer.	5
(b) The pace was too fast. Students were rushed.	3
(c) Too much time was wasted on simplistic matters.	1
(d) The main instructor spends too much time with individual students at the cost of the others.	1

[3]Considering the strong evidence that the course should be shorter, this comment may need to be viewed within that context. The students seemed to be expressing the feeling of not being familiar enough with the material despite the length of the course. This may reflect more strongly on the effectiveness, or quality, of the course rather than its length.

Table 18

Student Comments About Manuals and Instructional Aids

Comment summary	Frequency
1. The Operator's Manual [TM 11-5820-890-10-1, 1 MAR 88] needs to be improved: needs to be better organized, to have better separation of sections ("could not tell when section changed"), better arrangement & spacing of material, & clearer step-by-step directions, etc. "The 10-1 . . . manual needs to be rewritten [so the student can] understand more about the components. Instead of referring to different pages or the components' model numbers, the components need names. The 10-1 can be written in steps on how the SINCGARS works without reference to different pages or other TM."	17
2. Give all students a manual for reference & home study. "Didn't have an opportunity to use manual"; "never read manual"; "more manuals"; [etc.].	16
3. Need training films; more diagrams & illustrations. Use a large model or mockup of the radio so students can see the settings & follow procedures. There should be large charts at the front of the room that show the steps for each operation.	10
4. Provide handouts describing operational procedures (the manual doesn't help enough). Need a course notebook or syllabus to follow & use for reference. Shouldn't rely on student notes.	6
5. Miscellaneous:	
(a) The manuals need to be used more in class.	2
(b) The pocket manual [TM 11-5820-890-10-2] needs to be improved. Needs to be made out of plastic.	2
(c) The 10-1 & 10-2 manuals need to be combined: "Combine them so the soldier will never be confused [about] where to look for something."	1
(d) The manual & training should emphasize more strongly that the radio should not be operated with the power amplifier unless the vehicle engine is running.[4]	1

[4]See Operator's Manual, Special Instructions, p. 2-32.

Table 19

Student Comments About Instructors

	Comment summary	Frequency
1.	Instructors need more complete knowledge of system.	8
2.	More than one instructor in the room sometimes creates conflicts among them. The assisting instructors may interrupt the instructor in charge.	2
3.	Need military instructors--not civilian.	2

Table 20

Miscellaneous Student Comments About Human-Factors Issues

	Comment summary	Frequency
1.	The W2 RF cable is hard to install & is designed poorly.	2
2.	The radios should be raised or angled upward in the classroom to make it easier for students to view the display & controls.	1
3.	The radio needs a speaker or headsets.	1
4.	The radio is too complicated.	1
5.	The front panel needs a protective cover for field use.	1
6.	The cue signal should be received only by radios set on FH/M.	1
7.	The +4 to -4 window for time is not large enough.	1
8.	Time should not be destroyed by Z-A. The radio should have a permanent real-time clock with its own battery.	1

Evaluator Observations

The findings reported in this section are based upon observations of the training evaluator made during the conduct of the training classes. Those that involve human factors aspects of the radio constitute only a small fraction of the human factors findings that pertain to SINCGARS. Human factors findings are published in earlier reports (see Bibliography) and are not, therefore, repeated here.

Course Content

Training development. The SINCGARS training package contains no self-corrective or self-improving loop. That is, there appears to be no systematic, formal, effective mechanism whereby lessons learned are incorporated into future training improvements and development. Thus, some mistakes or inadequacies may be doomed to repeat themselves over and over again, and needed changes may not become incorporated into the instructional materials or procedures.

Net-control-station training. The basic operator course did not include formal NCS training (including retransmission training). Whether or not it would be desirable to include the training as a regular part of the course has not been addressed in this report. It is only mentioned here that operators who are familiar with those procedures may very well be able to function more effectively as net members and in emergency situations where NCS functions must be taken over by a net member. A substantial number of students pointed to the lack as a shortcoming of the training.

Prior familiarity with VINSON. The students in the large training class were asked if they had ever used the KY-57 (VINSON) before. Approximately 40% indicated that they had. The percentage who were skillful in its use, however, was probably much smaller. Whether this argues for the inclusion of VINSON training with SINCGARS training is moot; to the extent that operators (of the "vanilla" radio) are not familiar with VINSON, the inclusion of VINSON refresher training may be required.

Training aids. Attention needs to be paid to the legibility of training aids such as overhead projector slides. While the large majority of the 27 view graphs used in the present course were adequately readable, a few were borderline from a distance of about twenty feet, which was about at the back row of the class. Also, a number of students made the excellent suggestion that operational procedures be listed in steps on large charts and placed at the front of the classroom during training. The operator's manuals are not, as written, good training aids (although the smaller of the two is better); therefore, the addition of other, compensating aids, such as charts and mockups, should be considered.

Nomenclature. The first practical exercise in the course required the students to use the operator's manuals to identify the nomenclature associated with many components of the radio system. The students had difficulty finding all of the required information in the manuals. This exercise proved to be a very ineffective means of teaching a topic that, as it later became apparent, the instructors considered unimportant: On the last day of instruction, one of the instructors said to the class, "We could care less about nomenclature. What we care about is that you can operate the radio." The sentiment was laudable, but the remark brings into question the utility of the practical exercise dealing with nomenclature.

Radio transmit distance. There is general confusion about the nominal transmit distance associated with the high power setting: Some students were told that the distance is 8 kilometers; others were told 16 kilometers. The manual says 4 to 16 kilometers.

Troubleshooting. Troubleshooting is not emphasized in training. When students encountered a problem, they were shown how to overcome it but rarely encouraged to track down the cause of the problem themselves through a prescribed systematic review of the situation or by conducting appropriate tests.

Instructional Procedures

Student/equipment ratio. There was apparently little or no detrimental effect of class size and low radio-to-student ratio in the classroom--at least on criterion test performance and performance on the SLRT. This may argue that training can be successfully conducted with larger class sizes than previously expected. However, caution must be taken to maintain order and to ensure that the radios are distributed equitably among the students: It was once noted that while one of the radios was occupied by a single student, seven other students at the back of the classroom were not engaged in any training related activity. Similar inequities occurred from time to time, which subtracted from the amount of hands-on time for some students. The students made frequent comments indicating their desire for a larger radio-to-student ratio and expressing their frustration at having to share the equipment and learn at the same time. It is possible that the development of simulated radios could help to alleviate this problem at less cost than increasing the number of real radios.

Note-taking. The students were encouraged to take detailed notes during class. One of the reasons was the shortage of manuals. Note-taking in a class such as this is an ineffective method of ensuring that the students have a record of the instructional material presented. It would be more effective to prepare simple, concise, handouts for any material that would otherwise be recorded in student notes. The handouts could be used as preparatory material for midcourse tests. In this way, all students would be exposed to the same information as well as information that did not have to go through the error-inducing process of note-taking. Note-taking has many disadvantages and few advantages that cannot be achieved by other methods. The students did not have, nor were they provided with, adequate note-taking materials.

Intermediate testing. There was no effective midcourse testing to provide systematic and comprehensive feedback to students to enable them to gauge their progress through the course and their preparation for the final examination. One procedure that was attempted was only mildly successful: One student operated each radio while one to three others looked on. The observers were instructed not to assist the operator and to raise their hands if the operator made a mistake so that one of the instructors could assist in making the appropriate corrections. Not only did the observers assist the operator, contrary to instructions, but they would not point out errors to the instructors. So, while the experience may have had some value, it did not proceed as intended.

Assisting instructors. Assisting instructors occasionally compete with the ongoing instruction. Students who ask them questions or who are having operational problems sometimes become engaged in conversations or activities with the assisting instructors that temporarily distract the student (and possibly surrounding students) from the primary instruction.

Practical exercises. Systematic monitoring of practical exercises and free-play practice periods during the course was minimal. For the most part, students did not receive systematic individualized feedback on their performance unless they requested it from the instructors or encountered a problem that prevented continued operations.

Structured activities. (a) While a certain amount of experimentation on the part of the students should be encouraged--in general, it was not--some of the students, intrigued by the novelty of the equipment, moved ahead of the instructor, involving themselves in operational activities that temporarily interfered with their attention to the material being presented by the instructor. It is important, especially in larger classes, to provide structured activities that allow experimentation and practice, but also track the ongoing instruction. (b) It was noted on several occasions that students who were invited or encouraged by the instructors to engage in hands-on practice with the radios failed to do so. All students should be required to participate fully, and hands-on time should be distributed equitably among students. Otherwise, the more aggressive students receive more practice, while the more timid receive less or, as was the case with one of the observed students, almost none. (c) The lack of structure in student activities is generally wasteful of instructional time, again, especially in large classes. Most of the idleness referred to earlier can be attributed to a lack of structured scenarios for student activities.

Lesson plans. The training materials for the instructors included official lesson plans. Adherence to the plans was not strict, but all the material was covered. The implication here is not that the instructors should have adhered more closely to the plans, but that the plans could be more useful if they exhibited a greater sensitivity to classroom realities and provided for a much greater structuring of classroom activities.

Instructional setting. Instructors should be aware that the retention of skills and knowledge learned in a particular setting may suffer degradation when the student is asked to perform in a new setting. The relevance here is that the final examination (criterion testing) was conducted under very familiar circumstances for some students (same room, familiar instructor), but somewhat less familiar circumstances for others (different room, different instructor). Since the criterion testing was not used to eliminate students or to make differential assessments of them, the practical impact of such variables was nil for the FOTE SINCGARS operator training. It could, however, have practical implications in other situations. An attempt should be made to vary the instructional settings and circumstances somewhat and to treat all students alike.

Instructional realism. (a) For most of the course the instructors communicated over the radio in a voice loud enough for the students to hear without a receiver. Added realism could be achieved by using the radio's whisper mode and other techniques more frequently so that students would have to employ the tool they are learning to use in order to communicate. There were many student suggestions that the course be made more realistic. (b) Some exercises with the radio should be conducted in darkness to familiarize students with the difficulties that may be encountered operating at night, especially with the backpack configuration.

catch on the rear opening in the mounting adapter when the cable is being drawn through during installation.

SINCGARS Operator Post-Training Performance Decay (Review of Previous Findings)

Decay Findings: 1983-1984

The first decay assessment was performed by ARI in association with the SINCGARS Maturity Operational Test (MOT), conducted by the U.S. Operational Test and Evaluation Agency (OTEA) during the fall of 1983. The assessment included two primary samples: 23 cavalry soldiers and 27 artillery soldiers. There were also two other groups of 4 cavalry and 3 artillery soldiers.

The 23 cavalry soldiers received extensive operator training and practice: 2 weeks of classroom training, followed by 1 week of unit training, followed by 3 weeks of hands-on field practice--a total of 6 weeks of experience. The SLRT pretest was administered immediately after the field practice; the posttest followed after a no-practice period of 3.5 weeks. The mean decrement in performance level for this highly trained group was 2.0%. After an additional 28 weeks of no practice, the decay had increased to 10% for 10 of the operators who were still available for testing.

The 27 artillery soldiers received 1 week of classroom training, 1 week of unit training, and 2 weeks of field practice. However, in their case, the SLRT pretest was inserted between the classroom training and the unit training; the posttest, as before, was given just after the field practice. Thus, this group experienced additional practice between the pre- and posttests, rather than a period of no practice. Altogether they had 4 weeks of experience. Because of the absence of a programmed no-practice period, it was expected that they would not experience performance decay between the SLRT administrations. Apparently, however, they did. The decrement in performance level was 5.2%. After 27 weeks of no practice, only 6 operators remained from this sample. Their decay had increased to 31%.

The discrepancy between the cavalry and artillery soldiers cannot be satisfactorily explained because of the large number of uncontrolled and possibly confounding variables associated with the assessment. The results do reflect, however, that the amount of decay is a volatile quantity that can be expected to vary in a semi-predictable manner as a consequence of natural factors such as amount and concentration of training and the duration of intervals in which the soldiers receive no SINCGARS practice.

The results for the other 4 cavalry soldiers and 3 artillery soldiers were of interest despite the small sample sizes. They went through the same series of training events as their corresponding larger groups, except that after the first week, they were no longer exposed to the SINCGARS radio, but were switched to current inventory radios instead. Hence, they had, respectively, 1 and 2 weeks of SINCGARS classroom experience followed by what amounted to no-practice periods of 7.5 and 8.5 weeks. They suffered mean losses of 14.0% and 12.6% in their SLRT scores. These two groups, who received no post-training practice, may represent the real-world situation more so than the primary samples described above: They received no unit training or field

experience immediately after official classroom training--a situation that is expected to typify many soldiers' experiences.

Decay Findings: 1986-1987

A later decay study was performed by ARI in 1986 in conjunction with OTEA's non-developmental item (NDI) test of ITT SINCGARS and nine other non-ITT radios. Eleven combat arms soldiers received 30 hours of classroom instruction and 4.5 days of field exercise prior to the SLRT pretest. The posttest followed after a 5.5 week no-practice period, during which 13.5% decay occurred.

Shortly after the combat arms test, ARI also assessed performance decay in a group of soldiers who had participated in a special side test conducted by the SINCGARS Project Manager (PM) in association with the Signal School at Fort Gordon. The 29 soldiers, who possessed communications-electronics specialties, were given 25 hours of classroom training, followed by 10 days of no practice, followed by 11 days of field experience, followed by no-practice periods that differed from soldier to soldier, ranging from 8 to 18 days. The SLRT pretest followed the second no-practice period; the posttest followed a third no-practice period lasting 10 weeks. The decay over the third no-practice period was 4.4%.

Table 21 summarizes all of the SINCGARS operator learning-retention studies performed prior to the FOTE.

Post-FOTE Performance Decay

Procedure

Operator performance level was remeasured with the SLRT at the end of the field test phase of the FOTE and at approximately 30, 60, and 90 days after the end of the field test. Students from duty stations other than Fort Sill were not included in the retention study because of the logistic difficulties of retesting them. Retesting was additionally limited to the two (of seven) Fort Sill units that provided soldiers for the FOTE in the greatest numbers: The 4/31st Mechanized Infantry Battalion provided approximately 195; the 2/34th Field Artillery Battalion provided approximately 30. For each of the four retests, the two participating units were requested to make available specific soldiers whose names were taken, representatively, from alphabetized rosters of FOTE participants.

Table 22 summarizes the schedule of events for this retention study and shows the numbers of soldiers in the various subgroups. The numbers shown for "Classroom training" under "Subtotal" represent the subject pool from which the retention study participants were selected.

Table 22 also shows a 26-day period (day 85 to day 110) of operator "exposure" to the radio following the first SLRT retest. During this post-FOTE period, OTEA and Environmental Proving Grounds personnel conducted a

Table 21

Chronological Summary of SINCGARS Operator Performance Decay Study Results

Date:	1983	1983	1983-1984	1983-1984	1986	1986-1987
Occasion:	(MOT)	(MOT)	(MOT)	(MOT)	(NDI)	(PM)
Group type:	Cav[a]	Arty[b]	Cav[a]	Arty[b]	Cmbt Arms[c]	Comm Elec[d]
Event[e]	Data					
Classroom training (hours):	80	40	80	40	30	25
SLRT (pretest)						
Sample size:				27		
Score (% correct)				83.9		
No practice (weeks):						2
Unit/field training (weeks):			4	3	1	2
No practice (weeks):						2
SLRT (pretest)						
Sample size:	4	3	23		11	29
Score (% correct):	66.6	77.1	76.6		74	68
No practice (weeks):	7.5	8.5	3.5		5.5	10
SLRT (posttest)						
Sample size:	4	3	23	27	11	29
Score (% correct)	57.3	67.4	75.1	79.5	64	65
Decay (%):	14.0	12.6	2.0	5.2	13.5	4.4
No practice (weeks):			28	27		
SLRT (posttest)						
Sample size:			10	6		
Score (% correct):			68.9	57.9		
Decay (%):			10.1	31.0		

[a]Cavalry. [b]Artillery. [c]Combat Arms. [d]Communications Electronics. [e]Listed in chronological order. Events that were not applicable for particular groups at particular times are indicated by empty cells.

Table 22

Timeline for Post-FOTE Operator Performance Decay Study

Day	Event	Number of subjects: 4/31st	+ 2/34th	= Subtotal	+ Other	= Total
	Classroom training and SLRT pretest phase					
001-004, 005[a]	Classroom training & SLRT baseline test	76	6	82	15	97
008-011, 012[b]	Classroom training & SLRT baseline test	68	12	80	18	98
015-018, 019[c]	Classroom training & SLRT baseline test	36	7	43	30	73
022-025, 026[d]	Classroom training & SLRT baseline test	0	3	3	96	99
	Totals:	180	28	208	159	367
	Additional training phase					
037-039	Unit familiarization training			[All subjects]		
043-068	Field training (FOTE pilot test & field test phases)			[All subjects]		
	SLRT retest phase					
071[e]	SLRT retest 1	19	4	n/a	n/a	23
085-110	Post-training exposure (MINT)			[All subjects]		
113[f]	SLRT retest 2	22	2	n/a	n/a	24
148[g]	SLRT retest 3	11	0	n/a	n/a	11
182-183[h]	SLRT retest 4	13	8	n/a	n/a	21
	Totals:	65	14	n/a	n/a	79

[a]04 March 1988. [b]11 March 1988. [c]18 March 1988. [d]25 March 1988.
[e]09 May 1988. [f]20 June 1988. [g]25 July 1988. [h]28-29 August 1988.

"mutual interference" test (MINT) of SINCGARS at Fort Sill. The MINT used most of the operators who participated in the FOTE and all of the operators who were subjects in this retention study. The operators were exposed to the radio on a daily basis during the MINT: They turned it on and remained close by, but engaged in operational activities only if problems occurred that required manual manipulation of the controls; otherwise the radio was keyed automatically throughout the test. So, this period cannot be considered to be either additional training or a genuine period of no-practice. Indeed, its impact is not known, but it probably helped to maintain the operators' skill levels. Consequently, the SLRT retest scores obtained after the MINT are suspected of being somewhat higher than they would have been without the MINT. Thus, the performance decay figures derived from them may be spuriously low.

The SLRT baseline test was administered at four different times, a week apart, during the month of classroom training. Consequently the test-retest interval for a given SLRT retest varied across students according to the date on which they took the baseline test. Thus, each of the four retest groups itself consisted of four possible subgroups, each with a different test-retest interval. The procedure thus logically yielded 16 retention groups. The actual number of groups in the retention study, however, was 10: Two of the logical groups were empty--that is, there were no students in the retention study subject pool from the last week of training who were available for either the first or third SLRT retest (which reduced the number of groups to 14); furthermore four groups were combined with other chronologically adjacent groups because of small sample sizes. The 10 remaining groups are depicted in Table 23 where they are ordered, along with the 16 logical groups, from smallest to largest in terms of test-retest interval.

Results

Table 24 presents the results of the baseline and four retest administrations of the SLRT for the 10 decay groups. The retest percentages have been adjusted (via analysis of covariance procedure) to remove the effects of intergroup differences in baseline performance. The adjusted percentages thus allow more realistic comparisons among the groups. All unadjusted percentages were derived by taking the mean of individual percentages within the specified group.

Post-training performance decay. It was expected that the highest SLRT performance levels would be observed during retest 1, just after the field training. At that point the operators had had not only a week of classroom training but also another week of unit familiarization training and three weeks of intensive field training. To test this hypothesis, the data from groups 1, 2, and 3 (retest 1) were combined and compared with the combined data (retests 2, 3, & 4) of the remaining seven groups.

The difference between the two resulting groups in mean percent correct was tested for significance by analysis of covariance. The adjusted mean percent correct for retest 1 (groups 1, 2, & 3) was 79.1. For retests 2, 3, and 4 (groups 4 through 10), the corresponding adjusted mean was 63.6. The difference between the two means was statistically significant: $F(1, 76) = 36.09$ $p < .001$. This decrease in performance level, which occurred during the first 10 weeks of a 3 1/2-month period after the completion of training

Table 23

Design of Post-FOTE Decay Study

SLRT Comparison	SLRT base-line week[a]	Logical groups: Group[b]	Size	Test-retest interval (days)	Actual groups: Group	Size	Test-retest interval (mean days)
(#1)	4	1	0	44	n/a	n/a	n/a
Baseline vs.	3	2	9	51	1	9	51
post-field	2	3	8	58	2	8	58
training	1	4	6	65	3	6	65
(#2)	4	5	2	86			
Baseline vs.	3	6	9	93 --->	4	11	91.7[c]
post-MINT	2	7	3	100			
exposure	1	8	10	107 --->	5	13	105.4[c]
(#3)	4	9	0	121	n/a	n/a	n/a
Baseline vs.	3	10	2	128			
after no-practice	2	11	4	135 --->	6	6	132.7[c]
period #1	1	12	5	142	7	5	142
(#4)	4	13	1	155			
Baseline vs.	3	14	5	162 --->	8	6	160.8[c]
after no-practice	2	15	9	169	9	9	169
period #2	1	16	6	176	10	6	176

[a]The 4th week of the training month yielded the shortest no-practice interval for a given retest; the 3rd week, the next shortest; etc. [b]The group numbers in this column are not meant to correspond to the class numbers given in Table 1. [c]Calculated from the intervals weighted by their sizes.

experiences, represents a mean performance loss across groups 4 through 10 of approximately 20%. The intervening MINT exposure to the radio (see Table 22) suggests that this estimate of loss may be conservative.

Group decay differences within retests. As noted previously, each retest session included subjects with varying test-retest intervals because the baseline test was not administered on the same date for all students. To determine whether the observed performance differences among groups for a given retest were statistically significant, separate analyses of covariance were performed for each retest. The analyses revealed no statistically significant differences (Table 25), although it should be noted that the adjusted percentages generally decreased as the interval between baseline and retest increased (see Table 24).

Table 24

Comparisons of SLRT Baseline and Retest Results

			Mean percent correct (unadjusted and adjusted[a])							
			Retest 1 (post-field)		Retest 2 (post-MINT)		Retest 3 (after no practice)		Retest 4 (after no practice)	
Grp	Test-retest interval	Base-line %	%	($\%_{adj}$)	%	($\%_{adj}$)	%	($\%_{adj}$)	%	($\%_{adj}$)
1	51	75.3	80.9	(79.9)						
2	58	73.3	73.8	(75.0)						
3	65	65.1	73.0	(83.5)						
4	91.7	79.7			72.7	(66.8)				
5	105.4	71.9			62.7	(65.5)				
6	132.7	81.0					68.8	(61.4)		
7	142	76.2					59.4	(57.4)		
8	160.8	72.3							61.0	(63.4)
9	169	78.2							67.3	(63.0)
10	176	68.0							54.6	(61.8)

[a]In scoring the individual student's SLRT, the score is expressed as a percentage of total points possible. Each of the unadjusted group percentages shown in this table is the mean of the individual percentages in the specified group. The adjusted percentages have had the effect of differential intergroup baseline performance statistically removed.

Correlation Between Length of Test-Retest Interval and SLRT Performance. The Pearson product-moment correlation coefficient for the relation between test-retest interval and group mean percent correct was $r = -.85$ ($t[8] = -4.53$, $p = .01$ [one-tailed]), indicating a strong tendency (coefficient of determination = .72) for performance to decline during the first two months. This finding is portrayed in Figure 4, which plots for each retest the mean individual SLRT score (percent correct) for all persons who took the retest (irrespective of within-retest test-retest interval). By the fourth retest the decay is seen to level off. (Of course, it would be expected to continue at a slower and slower rate as time passed.)

Table 25

Covariance Analysis of Within-Retest Group Differences

Retest	Group	Mean $\%_{adj}$ correct[a]	Analysis of covariance results
1	1	77.9	$F(2, 19) = 1.23$, $p = .31$
	2	72.6	
	3	79.1	
2	4	67.8	$F(1, 21) = 0.03$, $p = 1.00$
	5	66.9	
3	6	65.7	$F(1, 8) = 0.12$, $p = 1.00$
	7	63.1	
4	8	62.3	$F(2, 17) = 0.09$, $p = 1.00$
	9	62.5	
	10	60.4	

[a]The adjusted means presented here are somewhat at variance with those show in Table 24 because the adjustments here were confined to estimates based only upon the subgroups within each retest group, whereas the adjustments in Table 24 were based upon all 10 groups. The latter therefore constitute better descriptors.

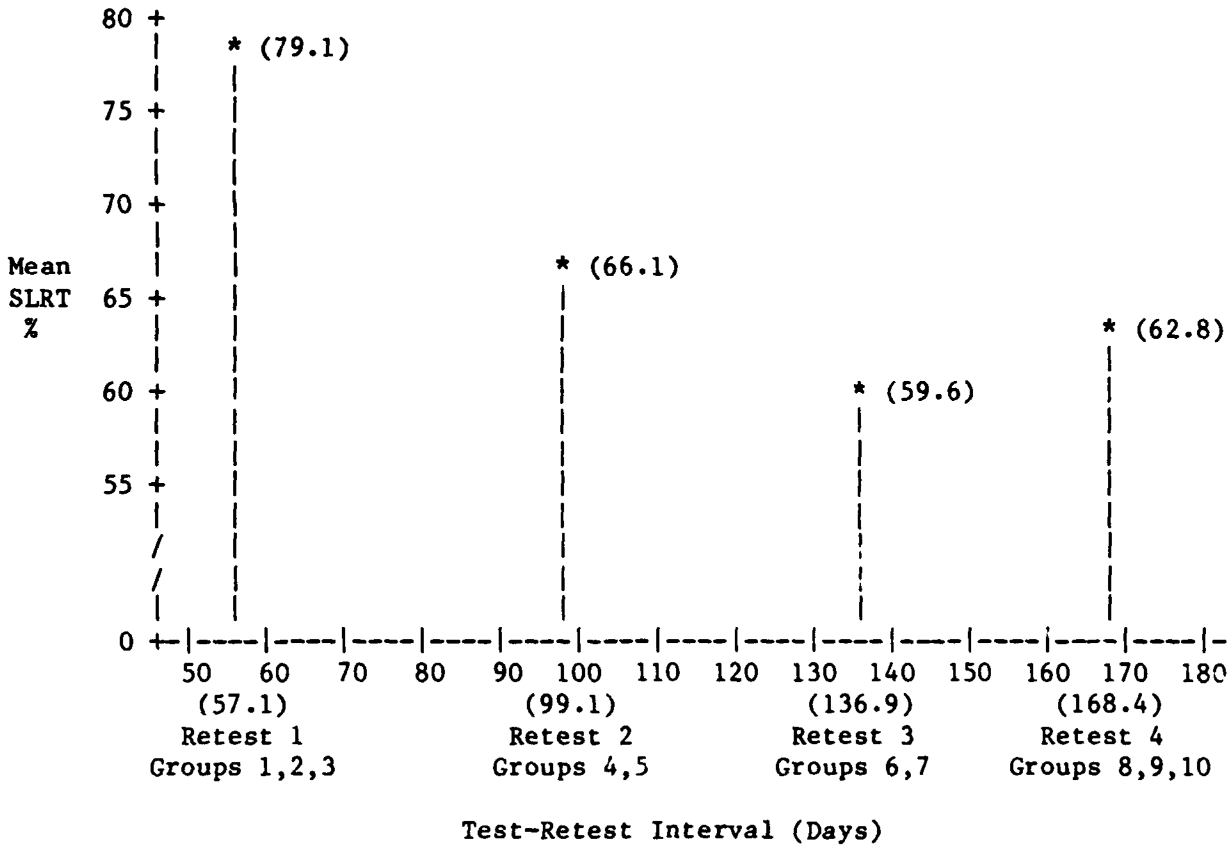


Figure 4. SLRT performance across time. (The numbers on the abscissa in parentheses are the mean test-retest intervals for the groups that participated in the retest.)

Effect of Decreasing Allotted Instructional Hours from 32 to 24

Procedure

As noted, the FOTE operator's course consisted of 32 hours of training plus 8 hours set aside at the end of training for testing. The course did not include NCS training. For the EUTE (fall 1988), the duration of training was 24 hours (three days) plus testing on the fourth day. Since the findings for the FOTE had shown more than a day of unused time, it was hypothesized that the 24-hour training course would be as effective as the 32-hour course. The test of this hypothesis consisted of comparing across the two courses the mean post-training performance time for completing the 18 critical tasks.

The procedure for collecting the data was identical to that described earlier in connection with the FOTE (see "Post-Training Testing: Criterion Test [Final Exam]). Differences in location (Fort Sill vs. Fort Hood) and other extraneous variables were considered to be of minor concern in this comparison. The sample size for the FOTE group varied slightly across critical tasks because of missing data on some of the tasks; it ranged from 361 to 364. The sample size for the EUTE was considerably smaller; it was 17.

Results

The data are shown in Table 26. Despite the differences in sample size, the differences for individual critical tasks were mostly quite small, and the difference between the two overall means was negligible (one second). To submit the latter difference to a statistical test was considered fatuous, and, therefore, no test was conducted. The data as a whole strongly supported the hypothesis that a 24-hour course would be as effective as a 32-hour course.

Also, under the circumstances, which were largely uncontrolled, it was judged best not to overinterpret the observed differences in performance times for individual critical tasks. It was felt that no useful inferences based on statistical significance or lack thereof would be warranted for any given difference. Therefore, they were not tested.

Table 26

Criterion Task Performance Times: FOTE (32 Hours Training) Versus EUTE (24 Hours Training)

Critical task	FOTE: Mean performance time	EUTE: Mean performance time
1. Assemble the SINCGARS AN/VRC-90 radio set	158	181
2. Turn on & test radio	20	25
3. Turn on, clear, & load TSEC/KY-57 (VINSON)	59	65
4. Set battery condition	14	14
5. Load manual, cue, & 2 single-channel frequencies	53	64
6. Perform communications check on manual channel	21	23
7. Set frequency offset on 1 channel	18	15
8. Perform channel scanning (non-priority)	36	31
9. Load & store TRANSEC variable	41	30
10. Load & store 2 hopsets	46	45
11. Load time-of-day	41	31
12. Perform communications check (frequency hopping)	32	13
13. Set radio for temporary storage	8	8
14. Cue the net control station	38	45
15. Prepare to receive ERF	17	17
16. Store ERF	15	21
17. Perform communications check (frequency hopping)	13	15
18. Zero radio, set for long-term storage, & disassemble radio set	92	98
Mean:	40	41

Note. Times are given in seconds.

Discussion and Recommendations

Operator Performance

Operator Performance, MOSs, and the ASVAB

The data on MOS were provided to indicate general characteristics of the subject sample for the FOTE. The relation between MOS and operator performance was not evaluated, although, in all likelihood, differences in SINCGARS performance would exist among the many MOSs in the Army. The question is largely academic, however, because the SINCGARS radio is a "general user item," which, in theory, all soldiers in the Army must be able to operate regardless of MOS or other qualification. As a general user item, SINCGARS must not necessitate special operator prerequisites beyond the SINCGARS training itself--such as MOS, Additional Skill Identifiers, and Special Qualifications Identifiers. Because of the general user status of the system, it is incumbent upon the developer to ensure that its complexity is minimized.

Similarly, it would not be desirable to observe strong relations between operator performance and aptitude variables such as those represented by various ASVAB scores, although, again, they would undoubtedly exist to a degree. In this study, the three ASVAB scores examined (EL, GT, and SC) were only mildly related to operator performance as measured by critical task performance on the SLRT and on the criterion tests (final exams). The most general of the three scores, GT, was least related to performance. Thus, although the question is complicated by sampling and validity factors, there appears to be no sizeable relation to these aptitude measures.

Operator Performance, SINCGARS Complexity, and Human Factors

Almost all of the many detailed human factors findings pertaining to the SINCGARS system are available in earlier reports (see Bibliography). Consequently, human factors was not stressed in this evaluation. It is worth reemphasizing, however, that the potentially huge training burden placed on the Army by SINCGARS is, by and large, a direct consequence of the lack of sufficient attention paid to human factors variables during the design and development of the system. The origin of most of the common performance errors, such as those observed in this study, can be traced, not to a lack of training, but to an inordinate operational complexity. As a general user item, SINCGARS should be operationally uncomplicated.

The great increase in complexity of this radio as compared with its precursors (some of which was unavoidable, owing to the far greater capability of SINCGARS), could have been minimized by special concern for the operator-system interface. Even at this late date, it would appear reasonable to take another look at the radio's display and keypad with a eye toward simplification. Changes in internal computer programming that would provide more display information (prompts and feedback) to the operator and reduce the often confusing aspects of the keypad operation could reduce training time significantly. Additional labeling changes on the keypad could also help. Training should not be the sole answer to solving the complexity problem. Training time is money that must be spent and respent throughout the life cycle of the system.

Operator Performance Decay Over Time

The several SINCGARS operator performance decay studies completed by ARI over the years were conducted in field research settings in which many relevant variables were uncontrolled. In fact, it is precisely because of such factors that so many decay studies were conducted. The findings have yielded values varying from 2% to 31% for groups differing in length of training, experience, and no-practice intervals, as well as other possibly relevant variables. Hence, it is difficult to be entirely specific about the degree of performance decrement expected after a given period of no practice. A reasonable generalization might be based upon an unweighted averaging of all of the data from all of the studies plus the assumption that decay tends to level off considerably after about 10 weeks. Such a calculation yields the following: For operators with approximately 4 weeks of training and experience followed by approximately 6 to 8 weeks of no practice, the expected decay is approximately 10 to 15%. Add a few more weeks and the decay may reach 20% or more. After this, performance would be expected to decline more slowly.

One factor that further confounds SINCGARS operator performance decay data is the lack of objective and independent measures of the quality of operator performance. Thus the notion of percentage decay brings to mind the question "Percent of what?" The normal, or mean, performance level on the SLRT is about 75 percentage points; a loss of, say, 13 points would reduce the performance level to about 65% (not 62%). But because there is, as yet, no adequate measure of how good 75% is, it follows that there is no adequate way of stating how bad 65% or a 13-point loss is.

About the only insight into this problem is the subjective realization of ARI evaluators and other test personnel that operators fresh out of training often have difficulty establishing frequency-hopping nets in the motor pool prior to going to the field. Consequently, additional practical instruction is typically given after classroom training but prior to the actual field experience. Often this additional training involves a week of "unit familiarization," and a week of "pilot testing." Both of these events entail considerable experience beyond that provided in the training course itself.

Subjectively, then, 75% indicates a level of post-training performance that is lower than desirable. Furthermore, the performance level appears to be unrelated to the amount of training typically received, as indicated in the present finding of no difference in SLRT performance after 24 and 32 hours of training. It seems, then, that training needs not to be longer, but better.

The Cost of SINCGARS Operator Training

It has been unofficially estimated[5] that the cost of Signal School training for one soldier for one week is about $1,000. From this figure, and certain assumptions, it is possible to derive a rough estimate of the lifecycle cost of SINCGARS operator training. It is estimated that the outside figure for that cost could be as high as $5.6 billion. The details of this estimate are shown in Table 27.

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[5] Office of the TRADOC System Manager for SINCGARS.

Table 27

Calculation of SINCGARS Maximal Life-Cycle Training Costs

• Initial force training:			
750,000	soldiers		
x $1,000	each	=	$750,000,000
• Plus first year remedial training:			
750,000	soldiers		
x $300	each	=	225,000,000
		Subtotal =	975,000,000
• Plus cost of training and maintaining force for one subsequent year:			
$975,000,000	original year cost		
x .25	turnover factor	=	243,750,000
• Plus cost of training and maintaining force for 18 remaining years:			
$243,750,000	cost per subsequent year		
x 18	remaining years in life cycle	=	4,387,500,000
		Total =	$5,606,250,000

The assumptions upon which Table 27 are based are the following:

- The life-cycle of SINCGARS will be 20 years.
- On the average, there will be 750,000 soldiers in the Army at any given time during the life cycle of the radio.
- Each soldier in the Army will receive 32 hours of operator training (including testing).
- Each soldier will be given 12 hours of remedial training per year.
- The cost of remedial training per hour will be the same as that of the initial training.
- Personnel turnover (new soldiers coming into the Army) each year will be 25% of the full force, i.e., 187,500.

Certainly each of the above assumptions can be challenged, and to the extent that they are modified, the entries in Table 27 would have to be

adjusted. Regardless, the cost of SINCGARS operator training would be very high even at half the amount estimated, especially in comparison with costs for the current PRC-77 and VRC-12 series radios, which has been estimated at about 6% of the estimate for SINCGARS.

Cost-Effectiveness Recommendations

Reduce currently allotted training time from 32 to 24 hours.

By far the most frequent complaint of the students was that the training course was too long. But an absolute standard for judging the efficiency of a course in its expenditure of time is, of course, not available. Despite this, the finding that 28% of the FOTE course time for students and 59% for assisting instructors was essentially wasted certainly suggests there is potential for considerable improvement in cost-effectiveness. Not all of the allotted instructional time is needed to teach the current subject matter. The truth of this assertion is strongly supported by the adjunct finding that students in a 24-hour course (for the EUTE) performed equally as well on their final criterion tests as the students in the 32-hour course (for the FOTE). The students were able to reach performance levels after 24 hours that were as high as those after 32 hours.

It makes sense, then, to pursue vigorously the notion that SINCGARS operator training (including testing) does not need to require a full week of the soldier's or instructor's time. Initial operator training could probably be shortened to three days rather than five with no other accompanying changes in format or content. The simple requirement that the course be conducted in three days rather than five would, if implemented, reduce the course by 40% with a concomitant reduction in costs. Based upon the maximal life-cycle cost projected above, a 40% savings could amount to $2.2 billion, or about $112 million per year. (See also discussion of group measures of performance below.)

Maximize class size.

It was true during the FOTE and EUTE that many variables with potential effects upon course conduct and student performance were uncontrolled--as is normally the case during operational testing. (One of the objectives of operational testing is to proceed under as realistic a set of circumstances as feasible.) It was fortuitous, for example, that the particular class of students observed during the FOTE was by far the largest of the 16 classes. It was shown, however, that class size seemed to have no detrimental effect on learning and performance. Consequently, it seems reasonable to increase class size as much as possible without diminishing returns in training effectiveness. The optimal size is, of course, an empirical question that should be addressed. The current study logically suggests that class size should be maximized, but the confounding presence of three instructors per classroom makes it difficult to suggest an optimal size without further research.

Maximize the student-to-instructor ratio.

Having three instructors per classroom appears to be very wasteful, considering that 59% of the assisting instructors' time was unused--even in the

largest of the classes. Various formats would be feasible, such as: (a) independent classes with two or three students per radio and one instructor; and (b) two or more related classes taught simultaneously by different instructors in which students in one could communicate with students in another, and instructors and students could exchange rooms or locations if desired for particular activities or segments of instruction. The relative efficacy of these or other alternatives should be evaluated through appropriate research.

Maximize the student-to-radio ratio.

While it was common for the students to express a desire for more radios, it does not necessarily follow that student performance would benefit by such an increase in equipment. In this study, it will be recalled, there was no obvious difference in performance between ratios of 3.2 and 1.7. Furthermore, the benefit must be weighed against the cost; although even at $10,000 per radio, the cost might be justified if significant performance benefit could be demonstrated in lower ratios. Of course, only so many students can crowd around a single unit, and the subjective impression gained by the evaluator is that four students per radio borders on being too many, while three is satisfactory. Again, the question is an empirical one that needs study.

Expand the curriculum beyond that contained in the FOTE course.

While the insertion of additional topics of instruction into the basic operator course will not reduce the cost of the course, it could very well make it more effective. In favor of such a notion is the finding that the 24-hour class for the EUTE covered more topics than the 32-hour FOTE course, apparently without a detriment to student performance. Apparently there is room both for a reduction in course duration and added instructional material.

The training should probably be broadened to include basic coverage of NCS tasks for all students regardless of whether they are slated to become NCS operators or outstation operators. An understanding of the NCS role should be useful to outstation operators in performing their own duties and in understanding the complexities of the system. Also, in emergency situations, net members would be more able to take over the role of the NCS operator. Other topics that should normally be taught include retransmission procedures, vehicular installation, data transmission, backpack configuration, remote operation, interfacing with other equipment, and troubleshooting.

Establish a 16-hour training goal, to be achieved through a rational program of research and development.

Beyond simply truncating 40% of the course time, a research and development program should be implemented with the goal of reducing the time requirement even further. The minimization of SINCGARS training expenditures, both of time and funds, cannot otherwise be achieved.

If a 24-hour course can be achieved with no training changes whatsoever (except a reduction in hours), it stands to reason that further reductions in training time could be achieved with a little effort--that is, through improvements in instructional methods and materials. It should be recalled here that the estimate of unused time in the course evaluated for this study

was an estimate of completely unused time--not of ineffectively used time. Had the estimate included time used ineffectively or non-optimally, then, no doubt it would have been considerably larger. Hence, there would appear to be considerable room for additional improvements that could cut course time even further.

The proposed research should exercise experimental control over training variables so that various training formats and methods could be adequately compared and appropriate instructional materials developed. The anticipated cost of the research would be minimal in comparison with the potential savings, which would amount to another 20% of $5.6 billion if the 16-hour goal could be achieved.

Such a research program should explore several areas, such as, but not limited to, the following:

Increased classroom structure. Classes should be highly structured, an element that was lacking to a considerable degree in the present course. Part of the reason for this lack was the excessive time allowed for a limited curriculum. There was simply nothing easily accomplished and readily available to fill the time except continued practice sessions for which no structured activities had been planned. Those sessions were, therefore, semiuncontrolled in character, and the usefulness of the time varied to a great degree as a function, not of the instructors, but of the students, some of whom used it beneficially while others wasted it. Practice sessions should include prescribed activities in which the students interact with the system in as realistic a manner as possible. Nets should be established that have definite missions to accomplish, and a certain amount of friendly competition should be established among the students.

Individualization of training. Keeping within cost and time constraints, training should be individualized as much as possible. Partially self-paced or programmed approaches should be tried. Related to this issue is the student-to-instructor ratio discussed above. The use of more than one instructor could help to individualize instruction, which is one of the main thrusts behind the use of multiple instructors. However, it was obvious in the present study that the mere presence of multiple instructors does not guarantee the efficient use of instructional time. The optimal number of instructors per classroom and the optimal number of students per instructor are questions that need to be distinguished, and further research should determine the optimum for each variable consistent with maximizing student performance in a cost-effective manner. Individualization of instruction must be considered in combination with other variables including not only the number of instructors and class size, but also instructional methods and materials.

Revision of the operator's manuals. Being substantially unchanged from earlier versions, both of the operator's manuals, the 10-1 and the 10-2, continue to need revision, especially the former.

Augmentation of training aids. Training aids to be considered should include an introductory video presentation, simple handouts, procedural charts, and possibly the development of some sort of simulated radios that would minimize the number of real (and costly) radios necessary for the

classroom. It is also possible that computer assisted instruction could be developed that would be beneficial, perhaps not so much in the classroom as in military units where remedial or refresher training is required for operators who have not used the equipment on a regular basis and for new personnel rotating into the units.

Development of performance criteria. The performance criteria provided by TRADOC for the FOTE and carried over to the EUTE should be discarded, and viable criteria for adequate performance of critical operational tasks should be developed. The primary purpose of such criteria would not be to fail students who do not meet them, but to constitute goals toward which students can strive and measures against which instructors can gauge student progress. The FOTE performance times were fairly well validated by those obtained during the EUTE training. Consequently, until further research is done, weighted averages from the two sets of figures should constitute useful indications of how fast the typical soldier will be able to perform critical operational tasks. To complement these criteria, a set of performance times is needed that is based on the performance of highly skilled and experienced SINCGARS operators. The latter scores would represent a ceiling on performance, beyond which a normal student would not be expected to perform.

Development of group measures of performance. SINCGARS testing has, to date, been conducted in individual, hands-on sessions in which the instructor runs the student through critical tasks and assigns a score of "go" or "no go." Needless to say, the procedure is time consuming. It should be possible to develop valid group measures that could be completed by the entire class in an hour or less. Such measures could also be used for intermediate testing during the course. A good example of such an instrument is the SLRT, which was used as a performance measure for this study. Such a test, if properly validated against independent measures of performance, would be far more useful than the "go/no-go" procedure currently in use. Not only would it be a time-saving device, it would provide much more information about the student's performance, which could be used as feedback to the student and as information useful to the development of performance norms.

Increased course realism. The course should strive for realism, especially after the basics have already been taught, by either simulating field situations or actually taking place in the "field" (motor pools or other field-like environments). Appropriate methods for enhancing realism need to be devised.

Compensatory training. Specific training steps should be taken to overcome equipment limitations or shortcomings, such as human factors problems cited here and elsewhere. Many of the common operator errors are directly attributable to human factors shortcomings. A striking case in point is the inability of students, upon completion of training, to test the radio's memories because of the lack of labeling on the Z-A position of the function switch. The task is intrinsically of minimal difficulty, requiring only that the operator move the function switch into the Z-A position and retain it there long enough to confirm the test in the display. A simple but conscious emphasis by instructors on the procedure and its usefulness should eliminate the problem easily. There are many operational situations requiring this sort of corrective instruction; they are detailed to a large extent in previous human factors reports pertaining to the SINCGARS system.

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Appendix A

Detailed Description of SINCGARS Critical Performance Tasks

Task 1: Assemble the SINCGARS AN/VRC-90 radio set:

a. Connect VINSON (TSEC/KY-57) cable CX-13293/VRC to receiver-transmitter (RT) RT-1439/VRC.
b. Snake CX-13293/VRC through RT mounting adapter AM-7239/VRC.
c. Slide RT into adapter & seat it.
d. Tighten left & right holding screws.
e. Connect W2 cable from antenna connector to power amplifier J2 connector.
f. Connect W4 cable from J5 connector on mounting adapter to AUD/DATA connector on RT.
g. Connect cable from J5 connector on RT to VINSON.
h. Connect handset H-250/U to J3 connector on mounting adapter.

Task 2: Turn on & test RT:

a. Move function switch from STW position to Z-A position.
b. Observe "good" (or fail message) in display.
c. Move function switch to TST position.
d. Observe "E...d" & "88888" in display; listen for tone & clicks, & observe "good" in display.
e. Turn function switch to SQ ON position.

Task 3: Turn on, clear, & load TSEC/KY-57 (VINSON):

a. Turn on VINSON.
b. Turn MODE switch to C position.
c. Key H-250/U to clear tone.
d. Turn function switch to LD position.
e. Connect KYK-13 fill device to VINSON.
f. Turn on KYK-13.
g. Turn KYK-13 switch to position 1.
h. Turn VINSON switch to position 1.
i. Key H-250/U, observe KYK-13 for light blink, & and listen for beep in handset.
j. Turn off KYK-13 & disconnect.

Task 4: Set battery condition in RT:

a. Set RT function switch to LD.
b. Press BATT/CALL & observe "00" in display.
c. Press CLR & observe "__" in display.
d. Key in the status numbers found on battery.
e. Press Sto/ENT & observe blink in display.

Task 5: Load manual, cue, & two single-channel frequencies into RT:

a. Set function switch to LD.
b. With channel switch in MAN position, press FREQ, CLR, & numbers of desired frequency.
c. Press Sto/ENT & observe blink in display.
d. Turn channel switch to CUE, press FREQ, CLR, & numbers of desired frequency.
e. Press Sto/ENT & observe blink in display.
f. Set channel switch to channel 1, press FREQ, CLR & numbers of desired frequency.
g. Press Sto/ENT & observe blink in display.
h. Set channel switch to channel 2, press FREQ, CLR, & numbers of desired frequency.
i. Press Sto/ENT & observe blink in display.

Task 6: Perform communications check on manual channel:

a. Set function switch to SQ ON.
b. Set mode switch to SC.
c. Set channel switch to MAN.
d. Depress P-T-T switch on H-250/U & talk to NCS.

Task 7: Set frequency offset on one channel:

a. Set channel switch to desired channel & observe frequency in display.
b. Press SEnd/OFST & observe "00" in display.
c. Press CLR & observe "__" in display.
d. Press 5 or 10 for a positive offset (or press SEnd/OFST for a negative offset & observe "- __" in display; then press 5 or 10.
e. Press Sto/ENT & observe blink & offset frequency in display.

Task 8: Perform channel scanning (non-priority):

a. Set function switch to SQ ON.
b. Set mode switch to FH.
c. Set channel switch to CUE.
d. Press Sto/ENT & observe "SCAn_" in display.
e. Press number 8.
f. Press P-T-T on H-250/U & observe channel number in display.

Task 9: Load & store TRANSEC variable into RT:

a. Set mode switch to FH.
b. Set function switch to LD-V.
c. Set channel switch to MAN (or any other channel except CUE).
d. Connect ECCM fill device to AUD/FILL connector.
e. Turn on fill device.
f. Turn fill device switch to T1 or T2 as directed.
g. Press H°Ld/0 on RT keyboard.
h. Observe "LOAd" then "Sto t" in display, listen for beep, observe "Cold" in display.

Task 10: Load & store 2 hopsets into RT:

a. Set function switch to LD.
b. Set mode switch to FH.
c. Set channel switch to MAN.
d. Connect ECCM fill device to AUD/FILL connector, & turn on.
e. Set fill device select switch to desired hopset (e.g., 1) & remain in MAN channel.
f. Press H°Ld/0.
g. Observe "STO _" in display.
h. Press number of desired channel (1) & observe "Sto 1" in display.
i. Press Sto/ENT & observe blink in display followed by hopset number (e.g., "F001").
j. Set channel switch to channel 1 & observe "F001" in display.
k. Repeat procedure for channel 2.

Task 11: Load time-of-day into RT:

a. Set function switch to LD.
b. Press TIME & observe "00" in display.
c. Press CLR & observe "__" in display.
d. Press mission day numbers (01) & observe "01" in display.
e. Press Sto/ENT.
f. Press TIME & observe "00 00" in display.
g. Press CLR & observe "__ __" in display.
h. Press time-of-day (12 00) based on NCS master clock & observe "12 00" in display.
i. Press STO/ENT when master clock is at exact time (to the second).

Task 12: Perform communications check (frequency hopping):

a. Set function switch to SQ ON.
b. Set mode switch to FH.
c. Set channel switch to channel 1.
d. Press P-T-T on H-150/U & talk to NCS.

Task 13: Set RT for temporary storage:

a. Set function switch to OFF.

Task 14: Cue net control station:

a. Set function switch to SQ ON.
b. Set mode switch to SC.
c. Set channel switch to CUE.
d. Turn off KY-57.
e. Key H-250/U handset for 4 seconds & release.
f. Wait 15 seconds for reply.
g. Repeat if necessary.

Task 15: Prepare to receive ERF [ECCM remote fill]:

a. Set function switch to LD.
b. Set mode switch to FH.
c. Set channel switch to MAN & observe "Cold" in display.

Task 16: Store ERF:

a. Observe SIG indicator, listen for beep, & observe hopset number in display; e.g., "HF200."
b. Press Sto/ENT & observe "Sto __" in display.
c. Press channel number specified by NCS for storing hopset.
d. Press Sto/ENT, observe blink & "F200" in display.

Task 17: Perform communications check (frequency hopping):

a. Set channel switch to channel containing hopset.
b. Press P-T-T on H-250/U & talk to NCS.

Task 18: Zero RT, set for long-term storage, & disassemble radio set:

a. Set function switch to Z-A & observe "good" in display.
b. Set function switch to STW.
c. Disconnect CX-13293/VRC cable from VINSON.
d. Disconnect W2 cable from power amplifier & RT.
e. Disconnect W4 cable from RT & AM-7239/VRC mounting adapter.
f. Disconnect H-250/U from mounting adapter.
g. Loosen RT holding clamps.
h. Pull RT & VINSON cable from mounting adapter.
i. Disconnect VINSON cable from RT.